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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification [6] : C22B 9/05, 21/06	A1	(11) International Publication Number: WO 96/39545 (43) International Publication Date: 12 December 1996 (12.12.96)

(21) International Application Number: PCT/CA95/00447

(22) International Filing Date: 28 July 1995 (28.07.95)

(30) Priority Data:
462,011 5 June 1995 (05.06.95) US

(60) Parent Application or Grant
(63) Related by Continuation
US 462,011 (CIP)
Filed on 5 June 1995 (05.06.95)

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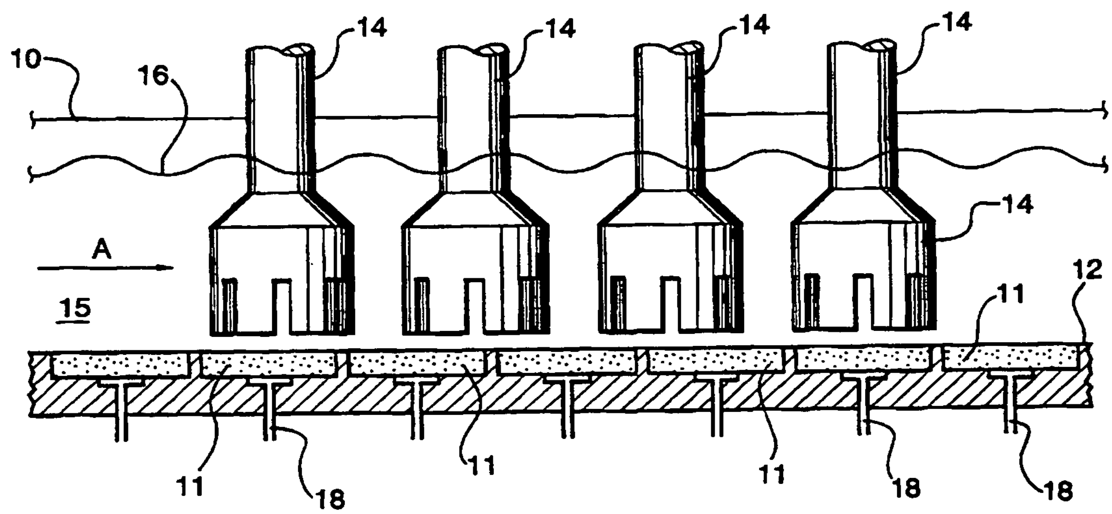
(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CN, CZ, DE, DK, EE, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, MW, SD, SZ, UG), European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: METHOD AND APPARATUS FOR CONTINUOUS IN-LINE GAS TREATMENT OF MOLTEN METALS



(57) Abstract

A method of and apparatus for treating molten metal to achieve effective removal of such unwanted inclusions as gases, alkali metals, entrained solids, and the like. The method comprises continuously introducing molten metal into a container forming a trough or trough section, such as the trough provided between a melting furnace and a casting machine, providing at least one mechanically movable gas dispenser (11) submerged within the metal (15) in the container and introducing a gas into the metal adjacent to a gas disperser (14) in a part of the trough forming a treatment zone such that the gas is broken into smaller bubbles by the gas dispenser (11) and dispersed through the treatment zone. The trough or trough section is such that it exhibits a metal holdup of less than 50 %.

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METHOD AND APPARATUS FOR CONTINUOUS IN-LINE GAS TREATMENT OF MOLTEN METALS

TECHNICAL FIELD

This invention relates to a method and apparatus for the treatment of molten metals with a gas prior to casting or other processes involving metal cooling and solidification. More particularly, the invention relates to the treatment of molten metals in this way to remove dissolved gases (particularly hydrogen), non-metallic solid inclusions and unwanted metallic impurities prior to cooling and solidification of the metal.

BACKGROUND ART

When many molten metals are used for casting and similar processes they must be subjected to a preliminary treatment to remove unwanted components that may adversely affect the physical or chemical properties of the resulting cast product. For example, molten aluminum and aluminum alloys derived from alumina reduction cells or metal holding furnaces usually contain dissolved hydrogen, solid non-metallic inclusions (e.g. TiB_2, aluminum/ magnesium oxides, aluminum carbides, etc.) and various reactive elements (e.g. alkali and alkaline earth metals). The dissolved hydrogen comes out of solution as the metal cools and forms unwanted porosity in the product. Non-metallic solid inclusions reduce metal cleanliness and the reactive elements and inclusions create unwanted metal characteristics.

These undesirable components are normally removed from molten metals by introducing a gas below the metal surface by means of gas injectors. As the resulting gas bubbles rise through the mass of molten metal, they adsorb gases dissolved in the metal and remove them from the melt. In addition, non-metallic solid particles are swept to the surface by a flotation effect created by the bubbles and can be skimmed off. If the gas used for this purpose is reactive with contained metallic impurities, the elements may be converted to compounds by chemical

reaction and removed from the melt in the same way as the contained solids or by liquid-liquid separation.

This process is often referred to as "metal degassing", although it will be appreciated from the above description that it may be used for more than just degassing metals. The process is typically carried out in one of two ways: (a) in the melting furnace itself, normally using one or more static gas injection tubes; or (b) in-line, by passing the metal through a box situated in the trough normally provided between a metal holding furnace and the casting machine, so that more effective gas injectors can be used. In the first case, the process is inefficient and time consuming because large gas bubbles are generated, leading to poor gas/metal contact, poor metal stirring and high surface turbulence and splashing. Dross formation and metal loss result from the resulting surface turbulence, and poor metal stirring results in some untreated metal. The second method (as used in various currently available units) is more effective at introducing and using the gas. This is in part because the in-line method operates as a continuous process rather than a batch process.

For in-line treatments to work efficiently, the gas bubbles must be in contact with the molten metal for a suitable period of time and this is achieved by providing an adequate depth of molten metal above the point of injection of the gas and by providing a means of breaking up the gas into smaller bubbles and dispersing the smaller bubbles more effectively through the volume of the metal, for example by means of rotating dispersers or other mechanical or non-mechanical devices. Residence times in excess of 200 seconds and often in excess of 300 seconds are required in degassers of this type to achieve adequate results. Effectiveness is frequently defined in terms of the hydrogen degassing reaction for aluminum alloys and an adequate reaction is generally considered to be at least 50% hydrogen removal (typically 50 to 60%). This results

in the need for deep treatment boxes of large volume (often holding three or more tons of metal) which are unfortunately not self-draining when the metal treatment process is terminated. This in turn gives rise to operational problems and the generation of waste because metal remains in the treatment boxes when the casting process is stopped for any reason and solidifies in the boxes if not removed or kept molten by heaters. Moreover, if the metals or alloys being treated are changed from time to time, the reservoir of a former metal or alloy in a box (unless it can be tipped and emptied) undesirably affects the composition of the next metal or alloy passed through the box until the reservoir of the former metal is depleted. Various conventional treatment boxes are in use, but these require bulky and expensive equipment to overcome these problems, e.g. by making the boxes tiltable to remove the metal and/or by providing heaters to keep the metal molten. As a consequence, the conventional equipment is expensive and occupies considerable space in the metal treatment facility. Processes and equipment of this type are described, for example, in U.S. Patents 3,839,019 and 3,849,119 to Bruno et al; U.S. Patents 3,743,263 and 3,870,511 to Szekeley; U.S. Patent 4,426,068 to Gimond et al; and U.S. Patent 4,443,004 to Hicter et al. Modern degassers of this type generally use less than one litre of gas per kilogram (Kg) of metal treated. In spite of extensive development of dispersers to achieve greater mixing efficiency, such equipment remains large, with metal contents of at least 0.4 m^3 and frequently 1.5 m^3 or more being required. One or more dispersers such as the rotary dispersers previously mentioned may be used, but for effective degassing, at least 0.4 m^3 of metal must surround each disperser during operation.

To avoid problems associated with deep treatment boxes, there have been a number of attempts at metal treatment in shallow vessels such as the troughs normally provided between metal holding furnaces and casting

machines. This would provide a vessel which could drain completely after use and thus avoid some of the problems associated with the deep box treatment units. The difficulty is that this would inevitably require a reduction of the metal depth above the point of gas injection while still allowing for effective gas/metal contact times. The use of gas diffusion plates or similar devices in the bottom of such shallow vessels or troughs has been proposed to introduce the gas and create the desired gas/metal contact. These are described, for example, in U.S. Patent 4,290,590 to Montgrain and U.S. Patent 4,714,494 to Eckert. However, bubbles produced in this way still tend to be too large and, given the reduced metal depth, such vessels or troughs necessarily must be made undesirably long to achieve effective degassing, and the volume of gas introduced must be made quite high (typically over 2 litres/Kg). As a result, the apparatus takes up a lot of floor space and the volume of gas introduced creates a risk of chilling the metal so that it may be necessary to provide compensating heaters. Such trough degassers can be drained, but because of the large bubble size they still require long residence times to effectively treat metal to the same degree of efficiency as obtained with other in-line methods. In addition, the introduction of large gas bubbles into a shallow metal volume results in excess surface turbulence and splashing. As a result, degassing in shallow troughs is not generally carried out on an industrial scale.

Thus there is a need for a metal treatment method and apparatus that provides effective treatment in short time periods, with correspondingly small volumes of metal, and with low gas consumption. Such processes and equipment would then be able to be carried out in metal delivery troughs with all the advantages of such devices that were noted above, but without the problems of high gas consumption or the space limitations noted.

DISCLOSURE OF THE INVENTION

An object of the invention is to enable gas treatment of molten metal to be carried out effectively in short time periods and correspondingly small volumes, using relatively low amounts of treatment gas.

Another object of the invention is to provide a method and apparatus for gas treatment of molten metal that can be carried out in small volumes of metal, and in particular in metal within metal delivery troughs or similar devices.

Another object of the invention is to provide a mechanical dispensing and dispersing system that operates within a small volume of metal, such as found in a metal delivery trough or similar device to achieve effective gas treatment.

Another object of the invention, at least in its preferred aspects, is to provide a method and apparatus for gas treatment of molten metal that allows the metal to be drained substantially completely from the treatment zone after treatment is complete.

Yet another object of the invention is to provide a method and apparatus for gas treatment of molten metal that avoids the need for metal heaters and bulky equipment.

These and other objects and advantages of the present invention will be apparent from the following disclosure.

It has now surprisingly been found that it is possible to carry out effective metal degassing in such containers, e.g. shallow troughs.

According to one aspect of the invention there is provided a method for treating molten metal with a treatment gas, comprising continuously introducing the molten metal into a container having a bottom wall and opposed side walls which form a section of a trough; providing at least one mechanically movable gas disperser within the metal in the container; introducing the treatment gas in the form of bubbles into the metal at a

point spaced from but adjacent to the gas disperser in a part of the trough forming a treatment zone such that the gas is broken into smaller bubbles by the gas disperser and is dispersed through the treatment zone; the trough section being such that the section exhibits a static to dynamic metal holdup of less than about 50%.

The dynamic metal holdup is defined as the amount of metal in the treatment zone when the gas dispersers are in operation, while the static metal holdup is defined as the amount of metal that remains in the treatment zone when the source of metal has been removed and the metal is allowed to drain naturally from the treatment zone.

According to another aspect of the invention there is provided an apparatus for treating molten metal with a treatment gas; comprising a container having a bottom wall and opposed side walls forming a trough for conveying the molten metal, the trough having a static to dynamic metal holdup of less than about 50%; at least one gas disperser in use positioned in the container submerged in the metal; means for moving the disperser mechanically; at least one gas dispenser located adjacent to the at least one gas disperser; and means for conveying gas to the at least one dispenser for introduction of the gas into the metal.

It is a surprising and unexpected feature of this invention that it is possible to operate gas dispensers and dispersers in such a way as to disperse gas sufficiently to generate the required gas holdup and gas-metal surface area within the constraints of the treatment zone, and further within a trough section. Prior art degasser methods generally do not achieve the high values of gas holdup and gas-metal surface area characteristic of the present invention. Furthermore, to maximize performance, prior art methods have relied on shear generation and mixing methods that have produced substantial splashing and turbulence at the metal surface, which has required the operation to be carried out in treatment segments of significantly larger volume than the

present invention. The prior art methods have therefore not been able to achieve the overall objective of effective degassing in short time periods.

Most advantageously, the present invention makes it possible to treat a molten metal with a gas while providing only a relatively small depth of metal above the point of dispensing or dispersing of the gas and consequently permits effective treatment of metals contained in small vessels and, in particular, in metal delivery troughs typically used to deliver metal from holding furnaces to casting machines. Such metal delivery troughs are generally open ended refractory lined sections and, although they can vary greatly in size, are generally about 15 to 50 cm deep and about 10 to 40 cm wide. They can generally be designed to drain completely when the metal supply is interrupted.

The invention, at least in its preferred forms, makes it possible to achieve gas treatment efficiencies, as measured by hydrogen removal from aluminum alloys, of at least 50% using less than one litre of treatment gas per Kg of metal, and to achieve reaction times of between 20 and 90 seconds, and often between 20 and 70 seconds.

It is preferred that the gas introduction take place via one or more fixed gas dispensers with gas outlets positioned directly below the gas disperser so that gas bubbles formed by the fixed gas dispensers rise in the metal and directly contact the mechanically movable gas dispersers. The gas dispensers can be in the form of one or more porous elements mounted in the bottom wall of a trough and connected to a source of treatment gas. The gas dispensers may alternatively be in the form of one or more tubes mounted in the bottom wall and connected to a source of treatment gas. The gas dispensers may further be in the form of one or more tubes mounted above the metal level in the trough and extending down into the metal, terminating at an outlet positioned below a gas disperser and connected at the upper end to a source of

treatment gas. It is preferred that there be one gas dispenser for each gas disperser, with its outlet positioned directly below the gas disperser so that the treatment gas bubbles upwards and contacts or is drawn into the region of influence of the gas disperser where it is efficiently broken into smaller bubbles and dispersed through the metal in the treatment zone.

Where gas dispensers are mounted in the bottom wall of the trough, it is particularly convenient to arrange the trough such that it has substantially zero static to dynamic metal holdup to avoid blockage of the gas dispensers by metal remaining in the trough between casts.

Because the gas bubble break-up and dispersion of this invention can take place in a shallow trough of the type used in transferring molten metal, it is possible and advantageous to use such a preferred configuration.

The mechanically moveable gas disperser provides two functions, namely to break up the treatment gas into fine bubbles, and to disperse the treatment gas bubbles. The gas bubbles are generated separately from the rotors in the molten metal by one or more fixed gas dispensers, and the mechanically moveable gas dispersers breaks up the gas bubbles and disperse them into the surrounding metal. The gas dispersers and gas dispensers act together to perform the metal treatment functions as previously described.

The gas disperser can be any mechanically moveable disperser device but it is particularly preferred that it be in the form of a rotary device. However, dispersers that oscillate or vibrate without rotation may also be used.

In operation, gas bubbles generated by the fixed gas dispensers are entrained in the molten metal and come in contact with the gas disperser where they are broken up and dispersed. In the case of the preferred rotary gas dispersers, the action of the disperser assists by drawing the metal into the disperser along with the entrained gas bubbles. It is therefore preferred that the gas disperser

be located sufficiently close to the dispenser so that the gas bubbles generated by the gas dispenser are substantially completely entrained in the molten metal being drawn into the disperser.

In some cases it may be desirable to allow some of the gas bubbles generated by the gas dispenser to escape without being further broken up by the disperser, which allows the overall gas bubble size distribution to be changed, and hence the effective reactivity for many metal treatment processes. This is accomplished, for example, by further separating the gas dispenser from the disperser. The maximum distance between the dispenser and disperser will depend to some extent on the shape and size of trough containing them and on the degree of metal treatment reaction desired and is a matter for simple experimentation, based on usual measurements of metal treatment efficiency (for example hydrogen levels in metal).

On the other hand, the gas disperser must be sufficiently far from the bottom of the trough to permit the flow of molten metal into the disperser and similarly the gas dispenser must not impede the flow of metal into the disperser.

In a preferred form of the invention, a metal treatment zone is provided within a metal delivery trough containing one or more generally cylindrical, rapidly rotating rotors acting as gas dispersers, each having at least one opening on the bottom surface, at least three openings symmetrically placed around the sides, and an internal structure such that the bottom openings and side openings are connected by means of passages formed by the internal structure through which molten metal can freely move; wherein the internal structure causes the treatment gas, introduced adjacent to the rotors, to be broken into bubbles and mixed with the metal within the internal structure, and further causes the metal-gas mixture to flow from the side openings in a radial and substantially

horizontal direction. It is further preferred that each rotor have a substantially uniform, continuous cylindrical side surface except in the positions where side openings are located, and that the top surface be closed and in the form of a continuous flat or frusto-conical upwardly tapered surface, the top surface and side surfaces thereby meeting at an upper shoulder location. It is further preferred that the side openings on the surface sweep an area, when the rotor is rotated, such that the area of the openings in the side surface is no greater than 60% of the swept area.

It is most preferred that rotors used in the invention as gas dispersers have internal structures consisting of vanes or indentations and that the side openings be rectangular in shape, formed by the open spaces between the vanes or indentations, and extending to the bottom of the rotor to be continuous with the bottom openings. The rotor as thus described preferably has a diameter of between 5 cm and 20 cm, preferably between 7.5 cm and 15 cm, and is preferably rotated at a speed of between 500 and 1200 rpm, and more preferably between 500 and 850 rpm.

It is further preferred that the rotors be rotated at a high speed sufficient to shear the gas bubbles in the radial and horizontal streams into finer bubbles, and in particular that the rotational speed be sufficient that the tangential velocity at the surface of the rotors be at least 2 metres/sec at the position of the side openings. Each rotor must be located in specific geometric relationship to the trough, and preferably with the upper shoulder of the rotor located at least 3 cm below the surface of the metal in the trough, and the bottom surface located at least 0.5 cm from the bottom surface of the trough.

There is also defined a treatment segment surrounding the gas disperser having a volume defined by a length along the trough equal to the distance between the trough

walls at the metal surface, and a vertical cross-sectional area equal to the vertical cross sectional area of the metal contained within the trough at the midpoint of the rotor. In some configurations, the gas dispersers may be located sufficiently close together that the distance between the centres of the dispersers is less than the distance between the trough walls at the midpoint of the disperser. Therefore, the treatment segment volume may be further defined as the volume defined by the vertical cross-sectional area of the metal contained within the trough at the midpoint of the gas disperser multiplied by the smaller of the distance between the trough walls at the metal surface and the distance between the centres of adjacent gas dispersers. The volume of the treatment segment is assumed to include the volume of the immersed portion of the disperser itself upon which the volume is defined. The rotor and trough are further related by the requirement that the volume of metal within the treatment segment must most preferably not exceed 0.20 m^3, and ideally not exceed 0.07 m^3. The treatment segment volume should, however, preferably be at least 0.01 m^3 for proper operation.

The fixed gas dispensers can also be advantageously used with mechanically moveable gas dispersers having three functions, namely gas introduction, bubble breakup and dispersion of the bubbles. This combination permits treatment gas to be introduced in two ways rather than solely by the mechanically fixed gas dispenser as previously described. It further permits the use of different treatment gases or gas mixtures in the two different introduction means. This is advantageous in permitting a reactive gas to be introduced through one means as a portion of the treatment gas mixture, and an inert gas to be used in the other injection means. Where one treatment gas or gas mixture requires less fine bubbles to be dispersed, introduction via the fixed dispensers may be advantageous.

The use of a fixed gas dispenser positioned closely adjacent to a mechanically movable gas disperser permits the effectiveness of bubble breakup and dispersion to be altered by varying the relative proximity of the two devices.

The volume limitations expressed for the treatment segment create a hydrodynamic constraint on the container plus gas dispensers and dispersers of this invention. The container as described above may take any form consistent with such constraints but most often takes the form of a trough section or channel section. Most conveniently this trough section will have the same cross-sectional dimensions as a metallurgical trough used to convey molten metal from the melting furnace to the casting machine, but where conditions warrant, the trough may have different depths or widths than the rest of the metallurgical trough system in use. To ensure that the gas dispenser and disperser are also in proper geometric relationship to the trough even when deeper trough sections are used, the trough depth must be limited, and this limitation may be measured by the ratio of static to dynamic metal holdup.

For the desired operation the static to dynamic metal holdup should not exceed 50%. From other considerations, it is also clear that residual metal left in the trough should preferably be minimized to meet all the objectives of the invention, and therefore it is particularly preferred that the static to dynamic metal holdup be approximately zero. Where practical situations require that a non-zero ratio of static to dynamic holdup be used, it is preferred that the ratio not exceed 35%, which permits the residual metal to solidify between casts and permits relatively easy manual removal of the residue. It is most convenient that the trough have opposed sides that are straight and parallel, but other geometries, for example curved side walls, may also be used in opposition to each other.

By associating a gas disperser with a defined volume

of molten metal (the "treatment segment" volume) it is ensured that the fine gas bubbles generated by the mechanical motion are properly dispersed fully through the treatment zone and therefore the requirement to achieve high gas holdup is met. It should be noted that although the total volumes of metal within a treatment zone of the present invention are substantially reduced over those in a deep box degasser for example because of reduced reaction time requirements, the number of gas dispensers may at the same time be increased because of the above requirements of the treatment segment.

It is most preferable and metallurgically advantageous in the present invention to carry out the gas treatment in a treatment zone consisting of one or more stages operated in series. This can be done in a modular fashion and it is possible, where space limitations or other considerations are important, to separate these stages along a metal-carrying trough, provided the total number of stages remain the same as would be used in a more compact configuration. It is also preferred that each stage comprise a gas disperser as described above and be delimited from neighbouring stages by baffles or other devices designed to minimize the risk of backflow, or bypassing of metal between stages, and to minimize the risk of disturbances in one stage being carried over to adjacent stages.

It should be understood that the term "treatment stage" refers to the general part of the apparatus adjacent to a gas disperser, and may be defined by baffles if they are present. The treatment segment, on the other hand is a portion of the container defined in the specific hydrodynamic terms required for the proper operation of the invention. It may be the same as a treatment stage in some cases.

More than one treatment stage may be provided along the length of the metal trough. The provision of plurality of treatment stages is (based on chemical

principles) a more effective method for diffusion controlled reactions and removal of non-metallic solid particles for metal treatment. The plurality of rotary gas dispersers within a directed metal flow as is created by the trough section operates (in chemical engineering terms) as a pseudo-plug flow reactor rather than a well-mixed reactor which is characteristic of deep box degassers.

It should be appreciated that within the operating ranges of number, size and specific design of rotors, rotational speeds, positions relative to the trough and metal surface, metal flowrates and trough sizes and shapes there will be combinations within these ranges which give the desired treatment efficiency in the short times required.

As a result of this the apparatus is also compact and can be operated without the need for heaters and complex ancillary equipment such as hydraulic systems for raising and lowering vessels containing quantities of molten metal. As a result, the equipment normally occupies little space and is usually relatively inexpensive to manufacture and operate.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a longitudinal cross-sectional view of a treatment zone consisting of a series of treatment stages containing a series of rotary gas dispersers and associated fixed gas dispensers in the form of porous elements mounted in the bottom wall of a trough section;

Figure 2 is a further longitudinal cross-sectional view similar to Figure 1, except that there is a single fixed gas dispenser associated with each rotary disperser, and the disperser also has provision for gas introduction;

Figure 3 is a further longitudinal cross-sectional view similar to Figure 1, except that the fixed gas dispensers are in the form of tubular elements mounted in the bottom wall of the trough section;

Figure 4 is similar to Figure 3 except that the

tubular elements enter the trough from above the metal;

Figure 5 is a side elevation of a first embodiment of a disperser in the form of a rotor for use in the invention;

Figure 6 is an underside plan view of the rotor of Figure 5;

Figure 7 is a side elevation of another embodiment of a disperser of this invention in the form of a rotor;

Figures 8(a), 8(b), 8(c) and 8(d) are, respectively, a side elevation of an alternative disperser, cross-sectional plan views taken on lines B and C respectively of Fig. 8(a), and underneath plan view of the disperser;

Figure 9 is a cross-section of a trough containing a disperser shown in side elevation showing how various dimensions are defined; and

Figure 10 is a side elevation of a further embodiment of a disperser for use in the invention.

BEST MODES FOR CARRYING OUT THE INVENTION

Figure 1 represents, in longitudinal vertical cross-section, a treatment zone in a metal delivery trough where gas is introduced via fixed gas dispensers 11 in the form of porous elements, mounted in the bottom wall 12 of the trough, separate from gas dispersers 14, but adjacent to them. The molten metal 15 (the upper surface 16 of which is indicated by the wavy line) passes successively past each disperser 14 in the direction of arrow A. The gas dispersers are of the rotary type, i.e. in use they are each rotated about their central vertical axes. The number of dispensers 11 does not necessarily equal the number of dispersers 14, and the dispensers can form a continuous porous layer on the bottom of the trough, if desired. The treatment gas is fed to the dispensers via orifices 18 in the bottom wall 12 of the trough, which are connected to a source of treatment gas (not shown). The porous elements and means to supply them with gas and to mount them in the bottom wall of the trough can be of the type disclosed for example in US Patent 4,290,590

(Montgrain) or US Patent 4,714,494 (Eckert), incorporated here by reference.

Figure 2 shows an alternative arrangement of gas dispensers 11 in the bottom wall 12 of the trough. In this arrangement, there is one gas dispenser 11 of the same type as in Figure 1 located centrally under each gas disperser 14, to maximize the contact between the treatment gas and the dispersers and to avoid the escape of gas past the dispersers. Also shown in this Figure are axial gas introduction passages 19 in each of the gas dispersers 14 which permit the use of different treatment gas mixtures within the same treatment zone, i.e. different gases may be introduced through dispensers 11 and passages 19.

In this type of disperser 14, metal is drawn up into the rotor and dispersed sideways. Placing the gas dispensers 11 directly below each disperser 14 will cause the gas bubbling up from such dispensers to be drawn into the disperser for effective breaking of the bubbles into finer bubbles and dispersion throughout the metal, in this case, along with gas delivered via the gas passages 19.

Figure 3 shows a third embodiment of fixed gas dispensers. The dispensers are in the form of simple tubes 11 mounted in the bottom wall 12 of the trough, and are located beneath rotary gas dispersers 14. By adjusting the distance 20 between the bottom of the gas dispersers 14 and the adjacent gas dispenser 11, it is possible to affect the degree of shearing of the bubbles and to alter their size, if desired for metallurgical reasons. By adjusting distance 20 a portion of the bubbles generates by the dispenser 11 can be made to bypass the disperser 14 (that is they are not drawn into the disperser in the metal which normally flows up into the disperser and out the sides). These gas bubbles which are therefore larger than those sheared by the disperser, will be mixed with the metal and finer gas bubbles exiting from the disperser to produce a gas bubble distribution

throughout the treatment zone which has a broader size range than otherwise obtainable, and therefore the degree of reaction with the metal can be altered and controlled by the adjustment of distance 20. The tubes 11 are preferably made of refractory or ceramic materials which can be readily joined to gas feeding manifolds or similar devices (not shown).

Figure 4 shows a fourth embodiment of fixed gas dispensers. The dispensers 11 are in the form of tubes 22 entering the treatment zone from above the metal and mounted above the metal (in a manner which is not shown), and terminating in an upwardly directed opening 23 underneath the gas dispersers 14. This embodiment is useful where there may be metal remaining in the trough between uses, since both the gas dispensers as well as the dispersers can be removed.

In operation using any of the fixed dispensers 11 described in Figures 1 to 4, a gas flow is preferably maintained from a time before the injector comes in contact with molten metal to a time after it is no longer in contact with molten metal to ensure that the gas orifices do not become blocked.

Any of the dispersers 14 shown in Figures 1, 3 or 4 can of course also be equipped with gas passages for the injection of additional treatment gas as described in connection with Figure 2.

Figures 5, 6, 7, 8(a), 8(b), 8(c), 8(d), 9 and 10 show designs of gas dispersers that are suitable for use in the invention. It will be understood that these dispersers are used with gas dispensers of the type shown in Figs. 1 to 4 even though they themselves are all capable of additional gas injection. The gas dispensers themselves have been omitted from Figs. 5-10 for the sake of convenience.

Figures 5 and 6 show a first rotary disperser design in a metal delivery trough suitable for use in an arrangement as shown in any one of Figs. 1 to 4.

The disperser 14 has a smooth faced rotor body 25 submerged in a shallow trough, formed by opposed side walls (not visible) and a bottom wall 12, filled with molten metal 15 having an upper surface 16.

The rotor body 25 is in the form of an upright cylinder 26 having a smooth outer face, mounted on a rotatable vertical shaft 27 of smaller diameter, with the cylinder portion having an arrangement of vanes 24 extending downwardly from a lower surface 28, and the outer faces of the vanes forming continuous smooth downward extensions of the surface of cylinder 26. As can be seen most clearly from Figure 6, the rotor vanes 24 are generally triangular in horizontal cross-section and extend radially inwardly from the outer surface. The vanes are arranged symmetrically around the periphery of the lower surface 28 in such a way as to define evenly spaced, diametrically-extending channels 29 between the vanes, which channels intersect to form a central space 30. An elongated axial bore 31 extends along the shaft 27, through the upright cylinder 26 and communicates with opening 32 at the central portion of the surface 28 within the central space 30. This axial bore 31 is used to convey additional treatment gas from a suitable source (not shown) to the opening or injection point 32 for injection into the molten metal.

The disperser 14 is immersed in the molten metal 15 in the metal delivery trough to such a depth that at least the channels 29 are positioned beneath the metal surface 16 and normally such that the cylindrical body is fully immersed, as shown. The disperser is then rotated about its shaft 27 at a suitably high speed to achieve the following effects. First of all, the rotation of the disperser causes molten metal and treatment gas bubbles from a gas disperser (not shown) to be drawn into the central space 30 between the rotor vanes 24 from below and then causes the metal and gas to be ejected horizontally outwardly at high speed through the channels 29 in the

direction of the arrows B (Figs. 5 and 6), thus forming generally radially moving streams. The speed of these radially moving streams depends on the number and shape of the vanes 24, the spacing between the vanes, the diameter of the cylinder 26 and the rotational speed of the disperser 14. Additional treatment gas may be injected into the molten metal through the opening 32 and is conveyed along the channels 22 in a co-current direction with the moving molten metal and bubbles from the gas dispenser in the form of relatively large, but substantially discrete gas bubbles.

The surface 28 between the vanes 24 at their upper ends closes the channels 29 at the top and constrains the gas bubbles and molten metal streams to move generally horizontally along the channels before the bubbles can move upwardly through the molten metal as a result of their buoyancy. Typically 4 to 8 vanes 24 are provided, and there are normally at least 3, but any number capable of producing the desired effect may be employed.

The rapidly rotating cylindrical disperser creates a high tangential velocity at the outer surface of the cylinder 26. Because the outer surface of the cylinder is smooth and surface disturbances from the inwardly directed vanes are minimized, the tangential velocity is rapidly dissipated in the body of the metal in the metal delivery trough. Consequently a high tangential velocity gradient is created near the outer smooth surface of the disperser. The rapidly moving streams of molten metal and gas exit the channels 29 at the sides of the dispenser body 25 and encounter the region of high tangential velocity gradient. The resulting shearing forces break up the gas bubbles into finer gas bubbles which can then be dispersed into the molten metal 15 in the trough. The shearing forces and hence the bubble size depend on the diameter of the disperser and the rotational speed of the disperser. Because there are no projections on the smooth surface of the disperser, and the outer ends of the vanes present a

relatively smooth aspect, the tangential velocity is rapidly dissipated without creating a deep metal vortex within the molten metal. A small vortex (not shown) associated with the rotation of the shaft 27 will of course still be present but does not cause any operational difficulties.

To facilitate the treatment of molten metal contained in shallow troughs or vessels such as metal delivery troughs, the rotor is preferably designed to inject the additional treatment gas into the molten metal at a position as close to the bottom of the trough as possible. Consequently the vanes 24 may be made as short as possible while still achieving the desired effect and the disperser is normally positioned as close to the bottom of the trough as possible, e.g. within about 0.5 cm, directly above a gas dispenser (not shown). However in some troughs of non-rectangular cross-section, the trough walls at the bottom of the trough lie sufficiently close to the disperser that the radial metal flow generated by the disperser impinges on the trough walls and causes excessive splashing. In such cases an intermediate location for additional gas injection more widely separated from the bottom of the trough will be preferable.

The apparatus makes it possible to disperse small gas bubbles thoroughly and evenly throughout a molten metal held in a relatively shallow trough despite the use of a high speed rotation disperser since vortexing and surface splashing is effectively prevented. By correct combination of the diameter, number and dimensions of vanes, rotational speed and distance from the gas dispenser (not shown), the dispersion of small gas bubbles is achieved without generating excessive outward metal flow that causes splashing when it reaches the sides of the metal delivery trough adjacent the disperser.

Figure 7 shows a second preferred embodiment of a rotary gas disperser for use in the invention. This

disperser represents a rotor having the same underneath plan view as the preceding disperser as illustrated in Figure 6. However, the disperser 14 is in the form of a smooth surfaced upright truncated cone 35, mounted on a rotatable shaft 27 of smaller or equal diameter to the diameter of the upper surface of the cone, with the conical portion having an arrangement of vanes 24 extending downwardly from the lower surface 28, where the outer faces of the vanes form continuous smooth surfaces projecting downwardly from the intersection of the surface of the cone 35 with the vanes 24. By reducing the surface area of the surface of the cylinder 26 as described in Figure 5 to the minimum required, the tendency to form a vortex is reduced over the embodiment of Figure 5, and hence permits operations over a wider selection of conditions within the disclosed ranges.

Figures 8(a), 8(b), 8(c) and 8(d) represent, respectively, an elevational view, two sectional plan views, and an underneath plan view of another embodiment of a rotary disperser suitable for use in this invention. The embodiment is similar to the embodiment of Figure 5 except that the cylindrical body 26 has a lower extending piece 26c in the form of a cylindrical upward-facing cup with an outer surface exactly matching in diameter and curvature the surface of the downward facing vanes 24. The cup has a central opening 45 in the bottom surface. By varying the diameter of the opening 45, the effectiveness of metal pumping can be controlled, thus allowing the radial and horizontal flow to be controlled without altering the tangential velocity of the cylindrical surface required to shear the gas bubbles.

Figure 9 describes the dimensional constraints as disclosed in this specification. Distance 60 is the immersion of the upper edge of the side of the disperser below the metal surface 16 and is preferably at least 3 cm. Distance 62 is the distance from the bottom of the rotor, measured from the centre of the rotor to the

vertically adjacent bottom of the trough (where the gas dispenser, not shown, is located) and is at least 0.5 cm.

Figure 10 shows the method of determining the open area of the openings in the side of a disperser of the type shown in Fig. 8. The openings 70 in the side of the disperser 14 on rotation describe a cylindrical surface lying between lines 71 and 72. If the area of this cylindrical surface is referred to as A_c, then the opening area ratio is defined as A_0/A_c and should preferably not exceed 60%. For rotors such as those illustrated in Figures 6 and 7, the line 71 would correspond to the bottom face of the rotor.

As noted above, a particular advantage of the apparatus of the present invention is that it can be used in shallow troughs such as metal-delivery troughs and this can frequently be done without deepening or widening such troughs. In fact transverse baffles (not shown) for dividing the trough into successive treatment stages may be fixed to the interior of the trough, if desired. Alternatively, assemblies of rotors, baffles and (if used in the manner of Fig. 4) gas dispensers 11 may all be mounted on an elevating device capable of lowering the components into the trough or raising them out of the metal for maintenance (either of the treatment apparatus or the trough e.g. post-casting trough preparing or cleaning).

The trough lengths occupied by units of this kind are also quite short since utilization of gas is efficient because of the small bubble size and the thorough dispersion of the gas throughout the molten metal. The total volume of gas introduced is relatively small per unit volume of molten metal treated and so there is little cooling of the metal during treatment. There is therefore no need for the use of heaters associated with the treatment apparatus. A typical trough section required for a treatment zone with only one gas disperser and one gas dispenser would have a length to width ratio of from

1.0 to 2.0. Although a treatment zone containing a single disperser and a single gas dispenser is possible, generally the treatment zone is divided into more than one treatment stage by transverse baffles (that have gaps to allow the metal to flow along the trough) containing one disperser per treatment stage meeting the treatment segment volume limitations given above. The method and apparatus for metal treatment in a treatment zone can thereby be made modular so that more or less treatment stages, dispersers and dispensers can be used as required. Moreover the treatment stages which comprise the treatment zone need not be located adjacent to each other in a metal delivery trough if the design of the trough does not permit this. The usual number of dispersers in a treatment zone is at least two and often as many as six or eight.

As indicated above, the metal treatment apparatus may be used for removing dissolved hydrogen, removing solid contaminants and removing alkali and alkaline earth components by reaction. Many metals may be treated, although the invention is particularly suited for the treatment of aluminum and its alloys and magnesium. The treatment gas may be a gas substantially inert to molten aluminum, its alloys and magnesium, such as argon, helium or nitrogen, or a reactive gas such as chlorine, or a mixture of inert and reactive gases.

Where gas injection in the treatment zone is accomplished by separate gas dispensers and gas dispersers, the introduction of a treatment gas containing the reactive gas (such as chlorine) via the fixed dispensers adjacent to the dispersers, with introduction of inert gas via the moving dispersers, will permit the chlorine to be dispersed as larger bubbles, whilst the inert gas will be dispersed as very fine bubbles.

This permits the effective reaction rates of the different gases to be adjusted separately. In addition, the use of fixed gas dispensers for the reactive gases provide for easier maintenance.

Claims:

1. A method of treating a molten metal with a treatment gas in which the gas is introduced into the metal in a treatment zone and is then dispersed in the metal located within the zone, characterized in that the molten metal is continuously introduced into a container having a bottom wall and opposed side walls forming a section of a trough exhibiting a static to dynamic metal holdup of less than 50%, a gas dispenser is positioned in the treatment zone forming part of the trough and is moved mechanically within the metal, and a gas is introduced into the metal adjacent to the dispenser such that the gas is broken into smaller bubbles by movements of the dispenser.

2. A method according to claim 1, characterized in that the gas is introduced via a fixed gas dispenser having a gas outlet below the gas dispenser.

3. A method according to claim 1, characterized in that the trough section exhibits a static to dynamic metal holdup of less than 35%.

4. A method according to claim 1, characterized in that the trough section exhibits zero static to dynamic metal holdup.

5. A method according to claim 1, claim 2, claim 3 or claim 4, characterized in that additional treatment gas is introduced into the metal via said dispenser.

6. A method according to claim 5, characterized in that said treatment gas and said additional treatment gas are different.

7. A method according to claim 6, characterized in that one of said treatment gas and said additional treatment gas includes a reactive gas.

8. A method according to claim 7, characterized in that the reactive gas forms part of said treatment gas.

9. A method according to claim 7, characterized in that said reactive gas is chlorine.

10. A method according to claim 1, characterized in that said treatment gas is introduced into the metal in the form of discrete bubbles before the treatment gas and entraining molten metal contact said gas dispenser.

11. An apparatus for treating molten metal with a treatment gas, having a container for the molten metal, a gas dispenser for introducing gas into the molten metal and means for conveying gas to the gas dispenser for injection of the gas into the metal, characterized in that the container has a bottom wall and opposed side walls forming a trough for the molten metal exhibiting a static to dynamic metal holdup of less than 50%, a mechanically movable gas disperser positioned within a section of the trough forming a treatment zone for the molten metal adjacent to the gas dispenser such that, in use, gas introduced by the dispenser is broken into smaller bubbles by movements of the gas dispenser.

12. Apparatus according to claim 11, characterized in that said gas disperser is movable in a manner selected from rotation about a central axis, oscillation and vibration.

13. Apparatus according to claim 11, characterized in that the gas dispenser is in the form of a porous element mounted in the bottom wall of the trough.

14. Apparatus according to claim 11, characterized in that the gas dispenser is in the form of a tube mounted in the bottom wall of the trough.

15. Apparatus according to claim 11, characterized in that the gas dispenser is in the form of a fixed tube extending downwards into the trough from above and in that the tube has an outlet below the gas disperser.

16. Apparatus according to claim 11, characterized in that the gas disperser contains means for injecting additional gas into the metal in the trough.

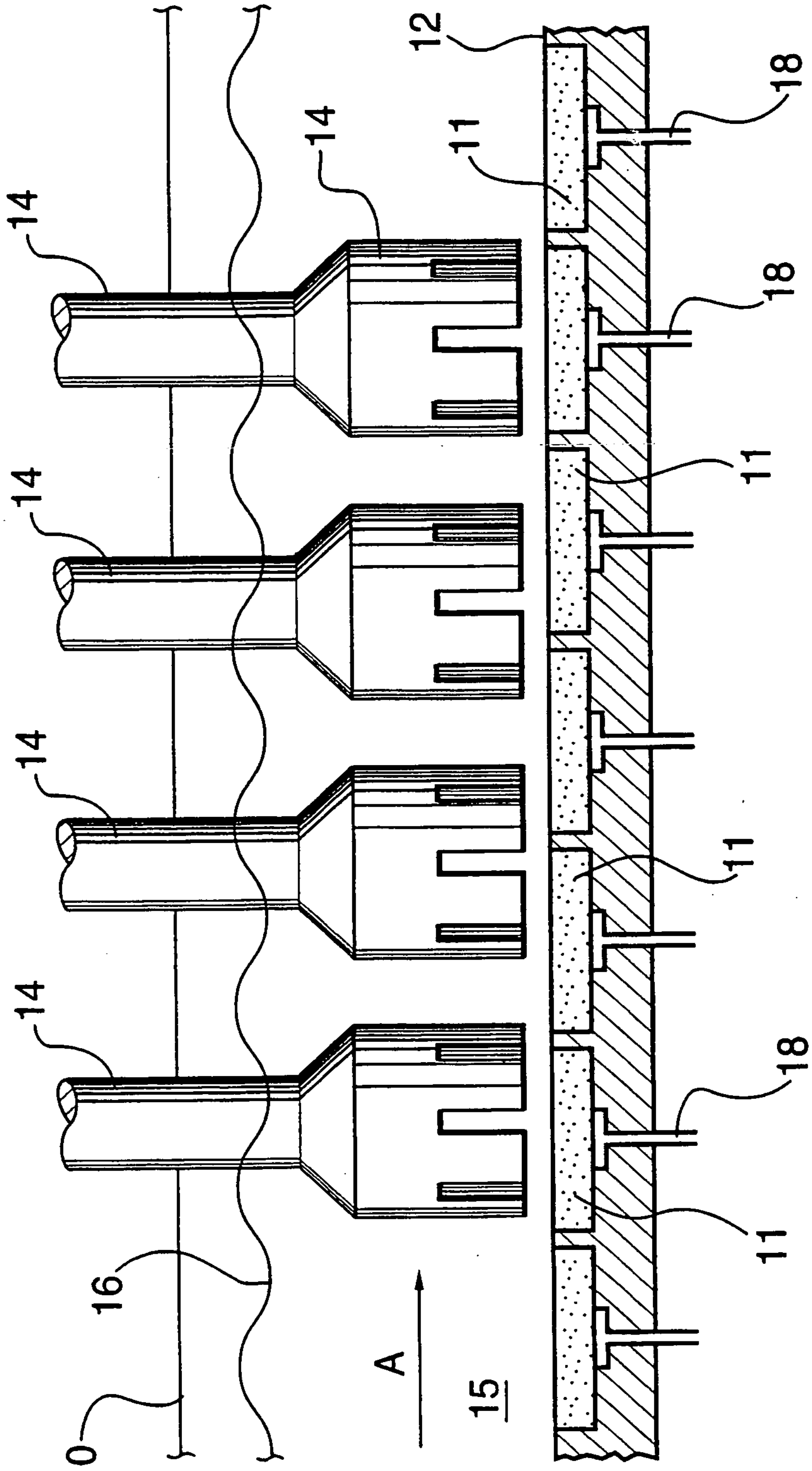


FIG. 1

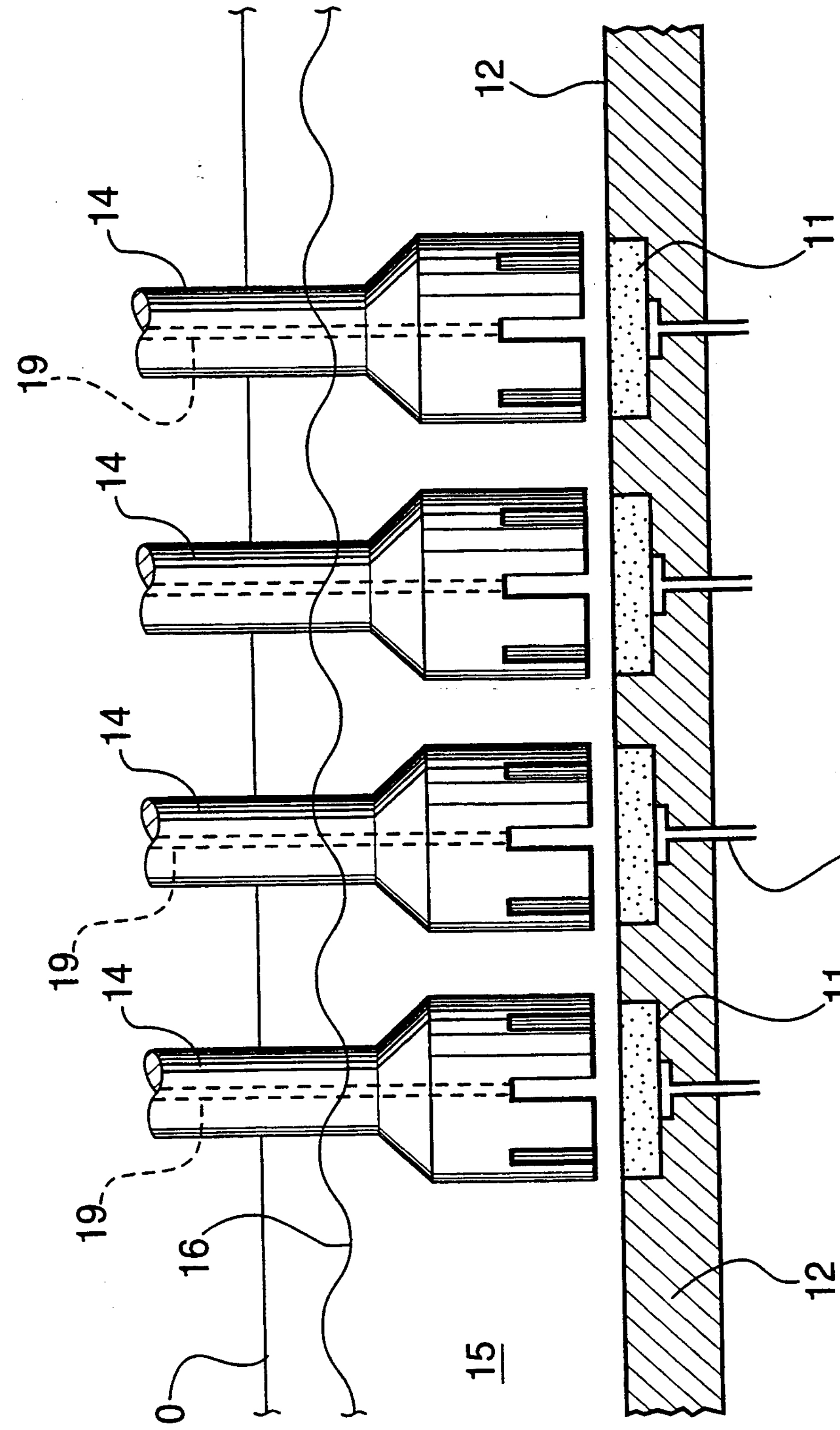


FIG. 2

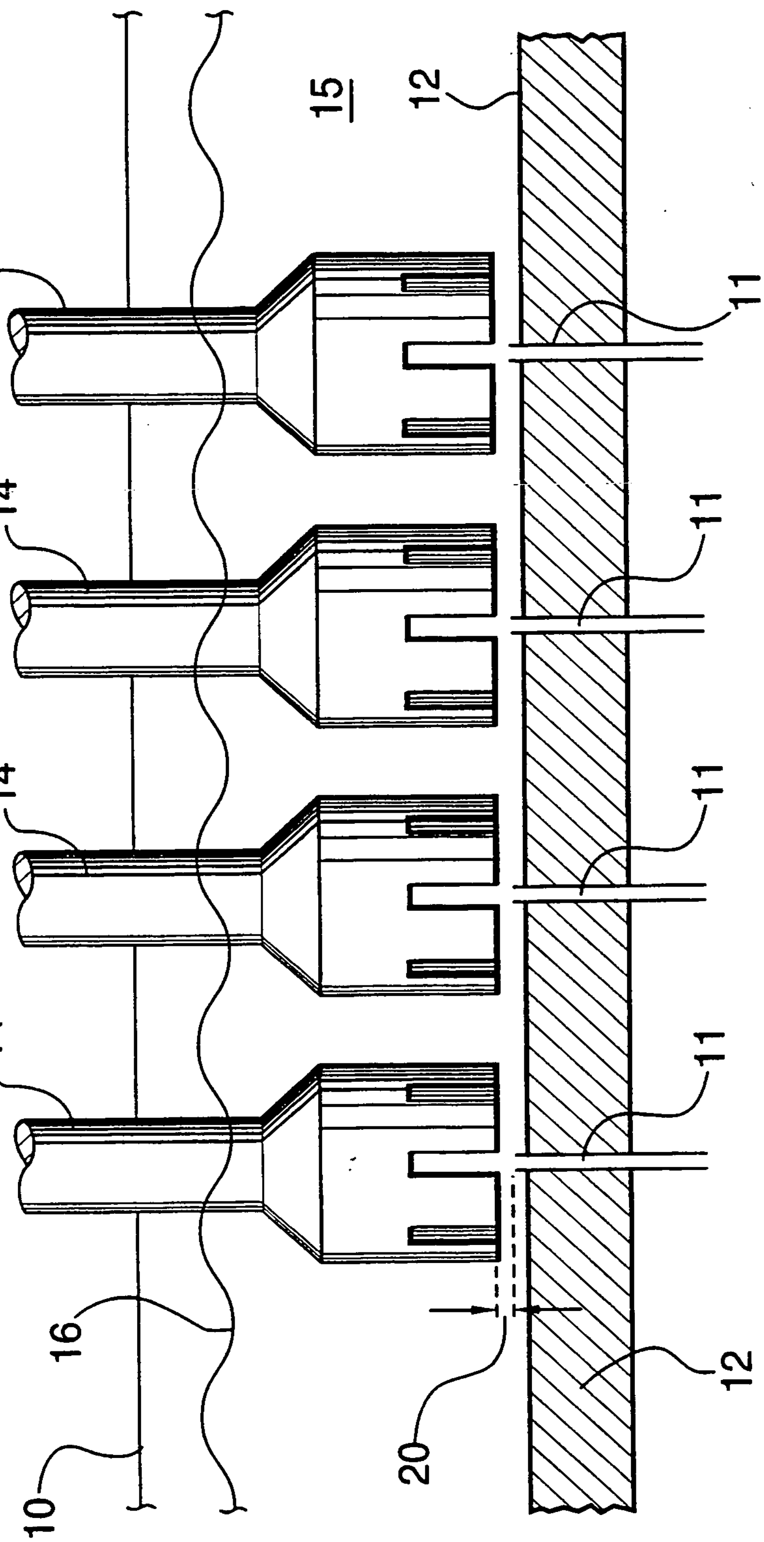


FIG. 3

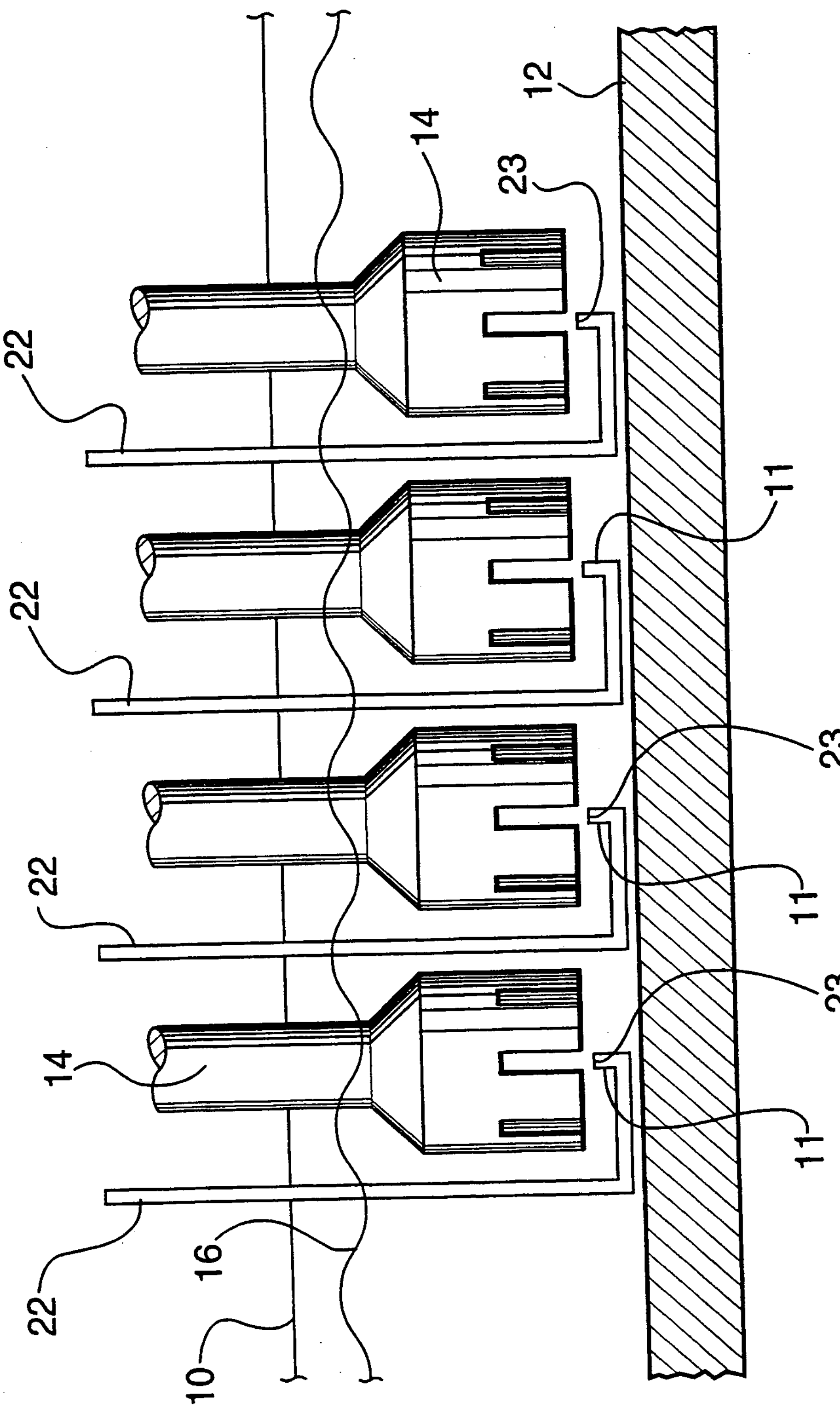


FIG. 4

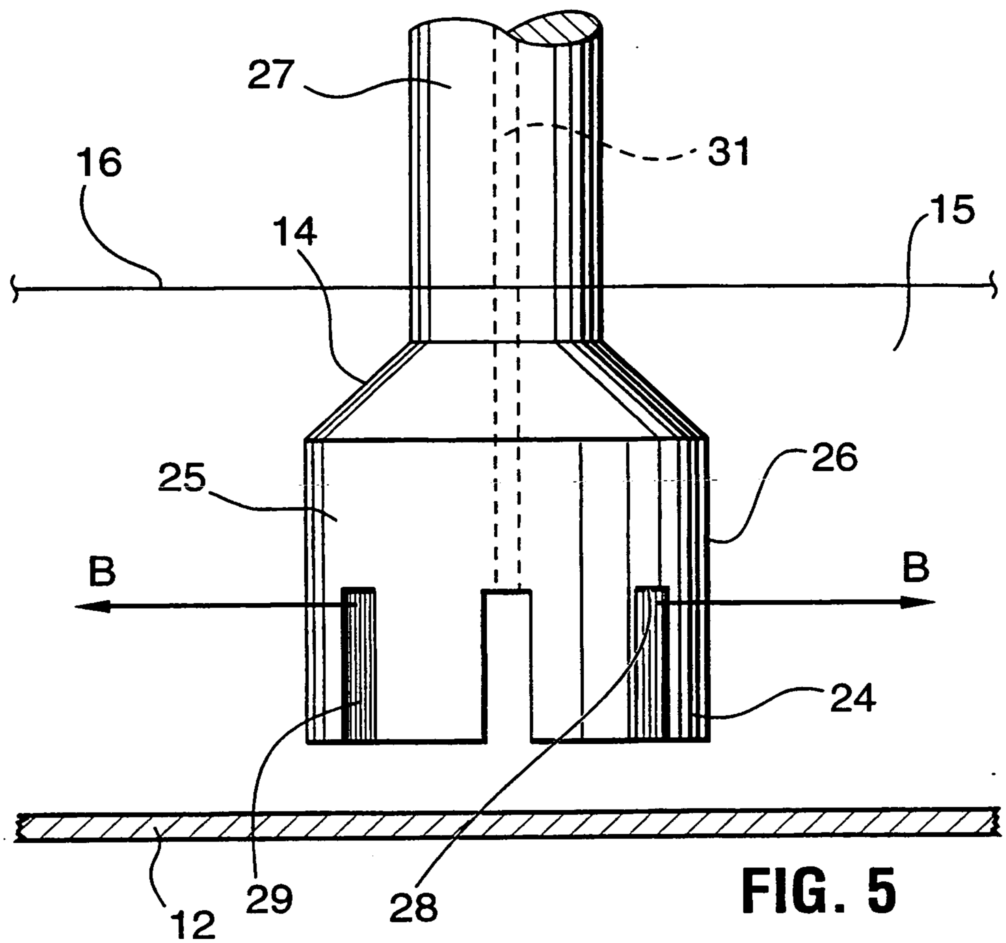


FIG. 5

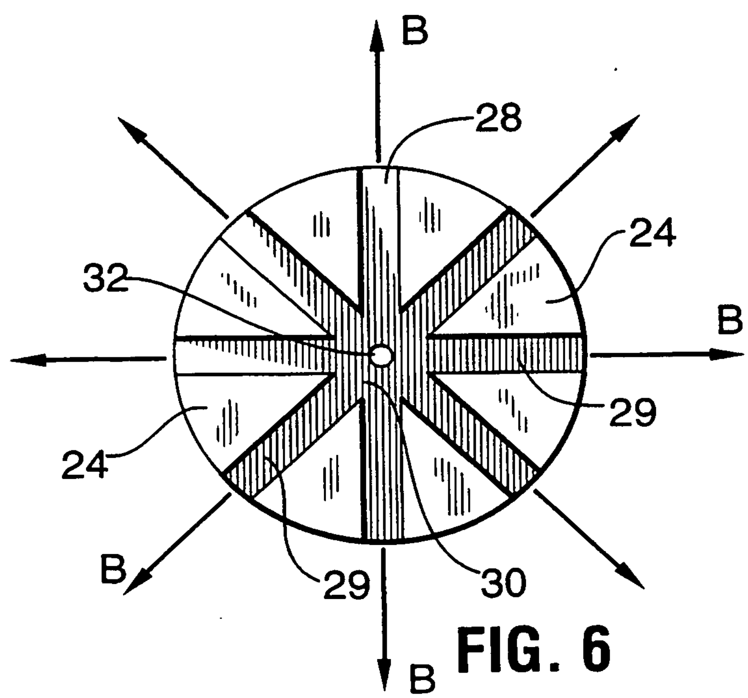


FIG. 6

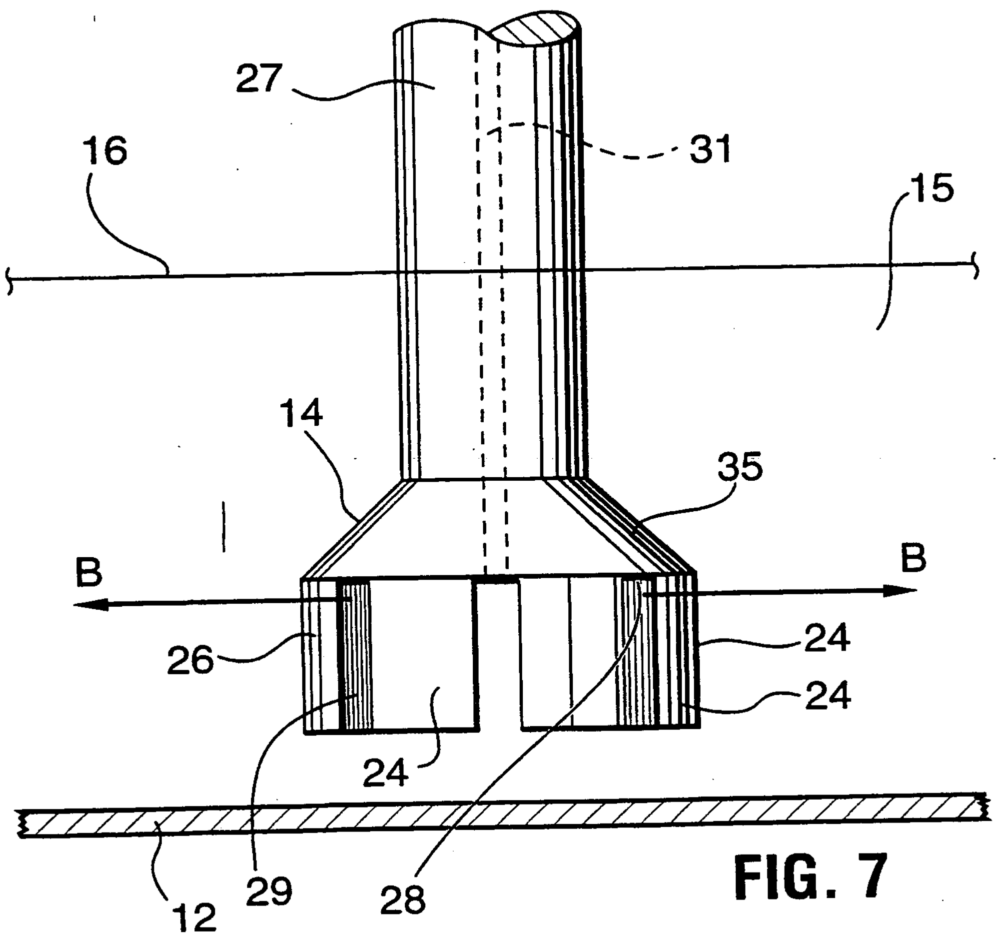


FIG. 7

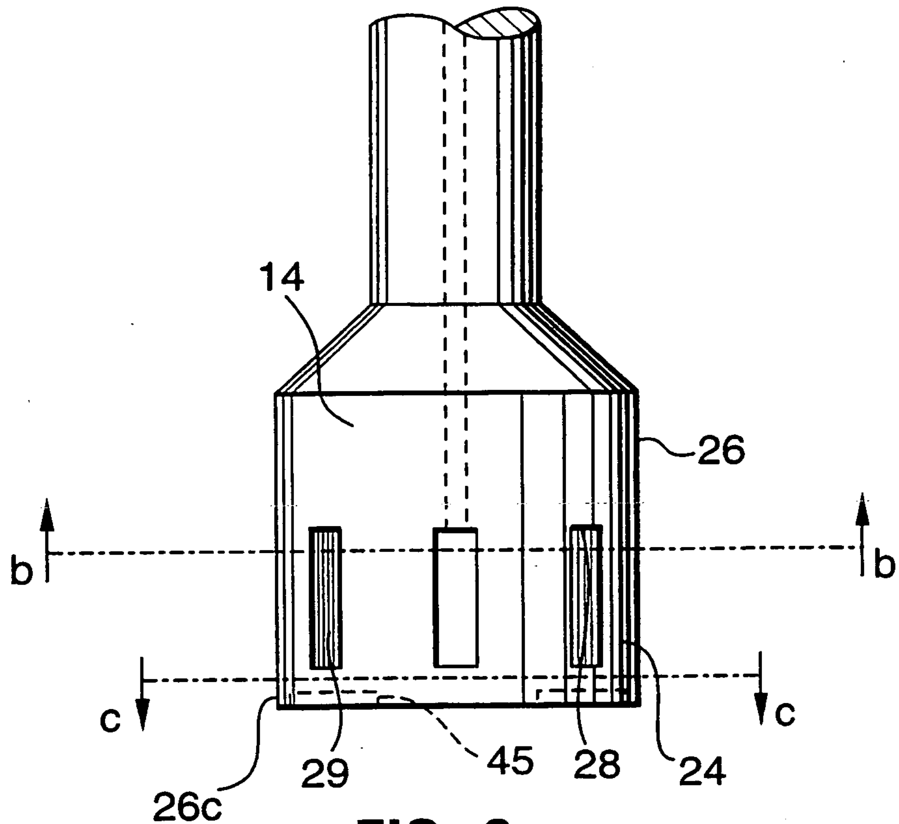


FIG. 8a

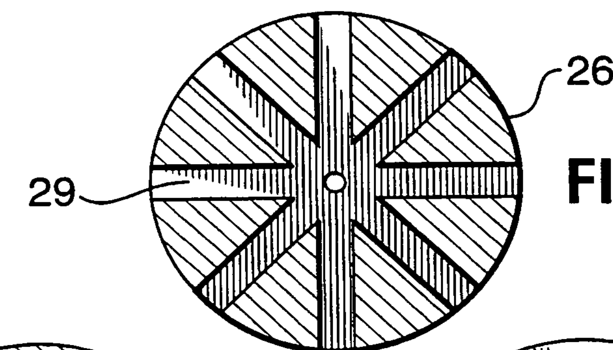
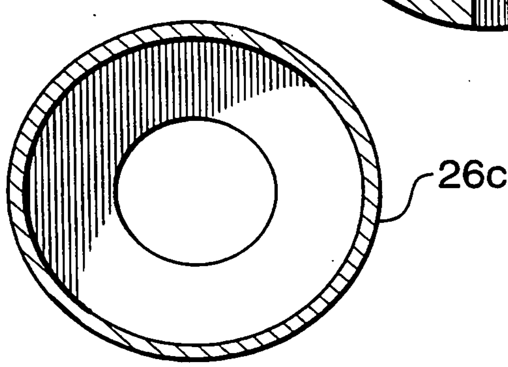


FIG. 8b



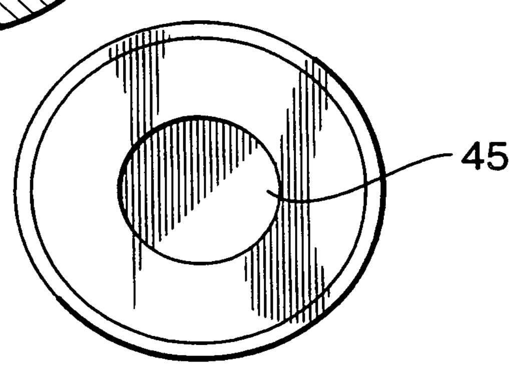


FIG. 8c FIG. 8d

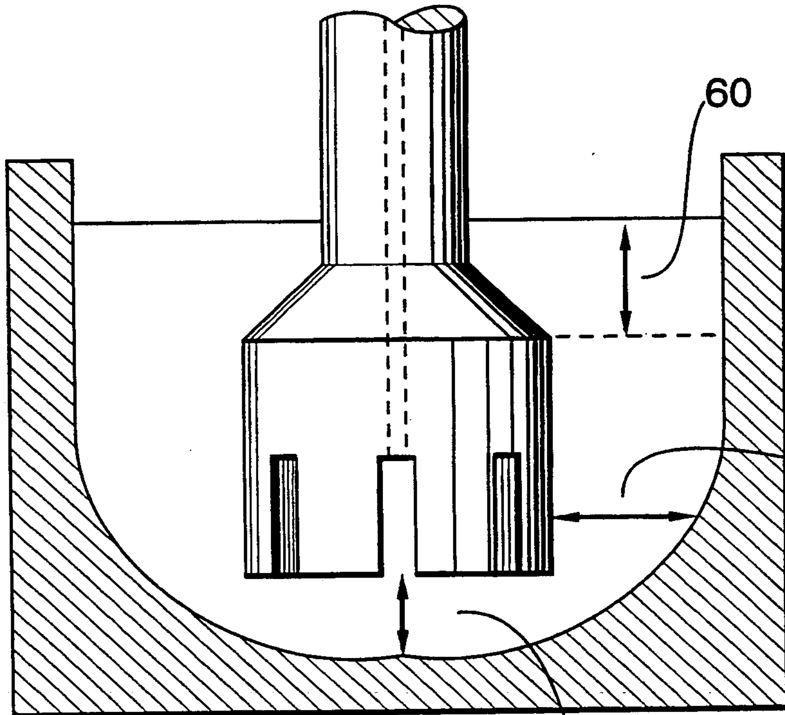


FIG. 9

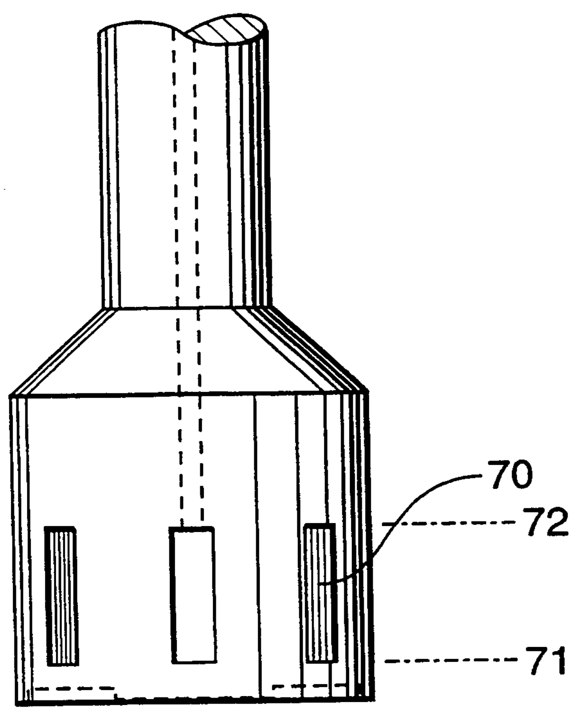


FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No
PC[illegible] 95/00447

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C22B9/05 C22B21/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C22B F27D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	FR,A,2 160 720 (FIRMA FRIEDERICH KOCKS) 6 July 1973 see page 2; claims; figure 1 ---	1,5
A	US,A,3 917 242 (BASS ET AL) 4 November 1975 see abstract; claims; figures ---	1,5
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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1

Date of the actual completion of the international search	Date of mailing of the international search report
9 February 1996	21.02.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Oberwalleney, R

International Application No
/CA 95/00447

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/[illegible] 95/00447

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